

XXVI. *An Experimental Enquiry into the Mineral Elastic Spirit, or Air, contained in Spa Water; as well as into the Mephitic Qualities of this Spirit.* By William Brownrigg, M. D. F. R. S.

Read June 13, 1765. **I**T is now twenty-four years since I presented to the Royal Society several Essays on Damps, which were read at the meetings, and are preserved among the papers of that most learned body. Those essays contained a few of the observations and experiments which I had collected, for a larger work, on that subject; and for which, as opportunity offered, I have since collected materials. And being desirous that some of my observations should be further verified, and more fully ascertained before they were made public, I therefore declined the honour of having those essays published among the Transactions of the Royal Society; esteeming it sufficient, at that time, to have excited several of my friends, and among these, Sir Hans Sloane, and the Rev. Doctor Hales, to communicate to me their sentiments on this subject.

In one of those essays I had occasion to remark,
 “ that a more intimate acquaintance with Damps
 “ and other mineral Exhalations might lead to a
 “ discovery of the nature and origin of those subtile
 “ and volatile principles, which enter the composition
 “ of various mineral waters, and are stiled their spi-
 “ rit;

“ rit ; on which their chief virtues are found to de-
 “ pend : and that some of those waters seem to be
 “ impregnated with exhalations that nearly resemble
 “ the fulminating-damp ; which, by its explosions,
 “ is found so destructive in coal-mines : while other
 “ waters are more evidently saturated with that most
 “ subtle and active exhalation, which, in many
 “ places, perspires from springs and lakes, and other
 “ openings of the earth ; or arises in pits and mines,
 “ where it is discovered by extinguishing flame ; and,
 “ from its pernicious effects, in killing all animals that
 “ breathe therein, is known to our miners by the
 “ name of choak-damp.”

This mephitic exhalation I, long ago, discovered
 to be a particular kind of air, or permanently elastic
 fluid ; and, from various observations and experiments
 related in the above-mentioned * essays, had reason
 to conclude, that it enters the composition of the wa-
 ters of Pyrmont and Spa, and of all others which,
 from their sharp and pungent taste, are stiled *acidulæ* ;
 and that it constitutes the volatile principle of those
 waters, called their spirit, on which their prime ver-
 tues chiefly depend ; altho’ it hath, hitherto, evaded
 the enquiries of the most skilful chemists, who have
 not been able to retain it in their vessels ; neither have
 they discovered any method of imitating it by their
 art.

In order the more fully to ascertain a fact of such
 importance, and to obtain a clearer knowledge of the
 nature of this spirit, I took the opportunity, while
 lately at Spa, to make a few experiments on those

* See Extract from Essay the fourth, which is published after
 these experiments.

celebrated waters; such as my engagements, and the apparatus that I could readily there procure, would admit of: The result of which experiments I now beg leave to lay before the Society.

EXPERIMENT I.

Having filled a common quart bottle with Spa water at the fountain Pouhon, I took a dried calf's bladder, made limber with oil, from which I carefully pressed out the air, by twisting it round, then drawing its orifice over the neck of the bottle, there tied it close, so as to leave an open communication between the water in the bottle and the empty cavity of the bladder, while the external air was excluded from both. I filled two other quart bottles with the Pouhon water, and fitted to them bladders in like manner. These bottles stood fourteen days, during the month of July, in a warm room; where I often examined them, expecting to have seen the bladders distended with air arising from the water. But in this was disappointed. For, during those fourteen days, I never could discover any air-bubbles adhering to the insides of the bottles; neither, from other signs, did it appear that any elastic substance was separated from the water; the bladders, all that time, remaining as empty as when first tied on. Some of the water, being then poured from each of the bottles, was found to sparkle more than when taken fresh from the fountain, and sooner to emit bubbles on the sides of the glasses into which it was poured: it was perfectly clear, and still retained its brisk and pungent taste, to which was added a taste from the bladders: but, in
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all other respects, it seemed as little altered as it would have been, had the bottles, which contained it, been all the while well closed with corks.

§ 2. In order more fully to ascertain the facts above mentioned, I filled two of those long vials, in which Frontiniac wine is usually kept, and two common quart bottles, with the Pouhon water, and fitted to them bladders in manner before related; excepting that the necks of the bladders were soaked in water, in order that they might better adhere to the glass than they did when moistened with oil. The water, thus excluded from any communication with the external air, stood seven days in a room, where it was continually kept lukewarm; the weather at that time being excessively hot, the mercury then usually standing from 80 to 85 degrees in Fahrenheit's Thermometer. During all that time, the bladders were not distended by any elastic substance arising from the water thus heated, but remained as empty as when tied to the vessels. The water in the two quart bottles, being examined after it had thus stood seven days, was clear, retained its brisk and sharp taste, and seemed in no wise decomposed; but, when poured into a glass, sparkled much, like wine on the fret. After a third part of the water was poured from one of those bottles, it was immediately closed with the hand, and shaken briskly about for half a minute; and being then suddenly opened, the air rushed out of it with an explosive noise, and more than ordinary violence, driving the water with great force, and dispersing it over the floor in a shower of seven yards in diameter.

It hath been shewn by Mons. Mariotte, that air is imbibed, in considerable quantities, by common water, and may again be separated from it, either by heat, or else by cold, as in congelation; or by removing from it the pressure of the atmosphere, as in the exhausted receiver of an air-pump. And Doctor Shaw relates *, that, without any of these aids, air separates spontaneously from the mineral water of Scarborough, and that, in a few minutes, he collected into bladders large quantities of air, from bottles of that water, after the manner attempted in the foregoing experiments; he also relates, that the air seemed to arise from the water with some degree of force, and continued long in an elastic state. The same experiment was since tried, by Doctor Home, on the Chalybeate waters of Dunse in Scotland †; who assures us, that he thus collected considerable quantities of true permanent air from those waters; which, with Doctor Shaw, he conjectures in no respect to differ from the common air of the atmosphere. And as I had no doubt of the accuracy and fidelity of those gentlemen in their experiments; and had entertained an opinion that the most spirituous acidulæ contained the most air, which, it was reasonable to suppose, might be separated from them in the same manner that it was separable from those that were less spirituous; I therefore was greatly disappointed in my expectations, when I could not obtain any air from the Pouhon water after the manner above related. I did

* See his Inquiry into the Contents, Virtues, and Uses of the Scarborough Spaw waters. Part II. Sect. IV.

† Essay on the Contents and Virtues of Dunse Spaw, Edinburgh, 1751. page 99, &c.

not, however, conclude, till after repeated trials, that air does not spontaneously separate from the Pouhon water, in such manner, and in so short a time, as it is said to separate from the Dunse, and Scarborough waters; and that, when excluded from the common air, it will, for several days, bear the greatest heats of the summer, usually found in the shade, at Spa, without parting with any of the air, or other principles of which it is composed. It is, however, manifest, that, by the heat applied in the above experiments, the Pouhon water was disposed more readily to part with its air, or some other elastic substance, than it is when taken cool from the spring: seeing that, when poured into a glass, after it had been thus heated, it sparkled more than when fresh drawn from the fountain, and flew with more violence when shaken in a bottle.

We may also hence learn, that when bottles filled with the acidulæ are broken, in hot, sultry weather, accompanied with thunder, as Hoffman and others have observed them, this accident must rather proceed from other causes, than from the expansion of their subtile mineral spirit, to which it is usually attributed. That flasks filled with the Pouhon waters, are liable to such accidents when unskilfully closed up, those, who fill them for exportation, have learned from experience. To prevent which, they suffer the flasks, after they are filled, to remain several hours in a warm air before they cork them up. And I found, that one of those flasks being filled to the neck, at the Pouhon spring, when Fahrenheit's thermometer stood therein at 53 degrees, the water had arisen near three quarters of an inch in the slender neck of the

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the flask, after it had stood, thus filled, for three hours, in a heat of 76 degrees: which rarefaction of the water, by the common heat of the air in summer, was more than sufficient to have broken the flask, had it been filled quite full with the water, and immediately closed at the fountain.

EXPERIMENT II.

I took one of the long Frontiniac vials, which might contain about 21 ounces avoirdupoise weight of Spa water, and which had stood seven days, in excessive hot weather, filled with Pouhon water, with a bladder fitted to it, as related in the foregoing experiments. The vial thus filled was placed in a copper vessel, so as to be immersed in water to two thirds of its height; and to the neck of the vial was fitted a kind of truncated cone, of spiral wire, to keep the bladder in an erect position. (See TAB.VII. Fig. 1.) The copper vessel was set over a slow fire, and the water therein heated to as great a degree as I could well endure with my hand; which I found to be about 110 degrees, according to Fahrenheit's scale. In this degree of heat, large bubbles of air soon began to arise to the top of the vial, forcing up with them small particles of water, which bedewed the sides of the bladder two inches, or more, in height. The vial being taken for a few moments out of the bath, the more exactly to view this kind of ebullition; very minute bubbles were observed to be formed, in the middle of the water, near the bottom of the vial; and from thence ascending with a rapid motion, and in continued streams, gradually to enlarge, until they flew

Fig. 1.



Fig. 4.

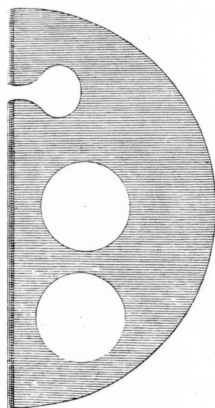
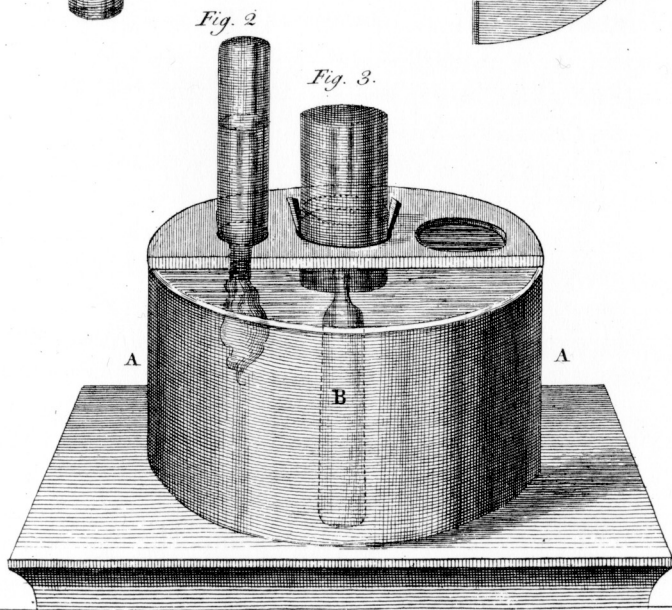


Fig. 2.



Fig. 3.



flew off, with a boiling motion, and considerable force, from the surface of the water ; which, by its dilatation, arose into the bladder. The vial was kept, in this moderate heat, two hours ; during which time, the bladder became more and more distended with the air, or other elastic substance, expelled from the water ; which was observed to acquire a muddy whiteness in proportion as the elastic substance was expelled from it. The bubbles, after about an hour and half, gradually lessened in number and size ; and, at the end of two hours, almost disappeared. The heat was then gradually increased for another hour ; at the end of which time the water in the copper vessel began to boil. And in this boiling heat the vial remained another hour ; when it being judged that all the elastic substance contained in the water was expelled from it, the vial was removed from the fire, after it had continued in the water bath four hours. From the time that the heat of the bath was increased, the water in the vial grew more and more turbid ; the earthy particles were formed into small masses, which were driven about by the heat. Towards the end of the operation, these earthy masses cohered into larger flocculi ; and from white became of a yellowish colour. These flocculi grew larger as the water cooled, and slowly subsided to the bottom of the vial. While the water in the vial was yet warm, the elastic substance that had been expelled from it was tied up close in the bladder, and then removed from the vial. The water in the vial, being corked up, was suffered to stand till perfectly cool. Being then examined, it was found to have got a taste from the bladder ; but was quite vapid,

having entirely lost its distinguishing brisk, sharp, ferruginous taste, as also its power of striking a purple colour with galls. The elastic substance contained in the bladder, when taken from the fire, appeared equal in bulk to half a pint of water. It lessened considerably in the cool air, for some days after it had been thus extracted, but did not afterwards seem to diminish much in bulk, tho' kept for a month in the bladder.

§ 2. I had several times occasion to repeat the above operation; and found that all the elastic substance could scarce be expelled from fresh Pouhon water, by the above degrees of heat, in a much shorter time than that employed in the foregoing experiment. For a common quart flask of this water, having been kept three hours in a water bath, heated to as great a degree as I could well endure with my hand (which might be about 130 degrees, according to Fahrenheit's scale), and having afterwards stood twenty-four hours before the bladder was removed from it; when opened, was found turbid, but had not deposited all its earthy particles, and still retained a little of its brisk taste. Another flask of the same water, fitted in like manner with a bladder, was kept two hours in a scalding heat (of about 160 or 170 degrees of the same thermometer), so that most of its elastic substance seemed forced from it; yet, when the flask was opened the next day, the water struck a purple colour with galls, and had not quite lost its sharp subastringent taste; and after about a third part of this water was poured out, and the rest shaken briskly in the close flask, and then suddenly opened,

opened, an elastic substance was still discharged from it, with a considerable explosion.

From these experiments we learn, “ that the Pouchon water contains a large quantity of a very subtile, light, and permanently elastic fluid, or of true mineral air ; and that this aërial fluid is closely united to the other principles of which this water is composed.” For, from Experiment the Ist, it appears, that when this water is excluded from all communication with common air, and at the same time liberty is given to the aërial fluid contained therein to expand, and to fly from it, with the same facility as from the water in an open vessel ; yet, under these circumstances, this elastic fluid does not exert its power of expansion, but remains so firmly united to the other principles of this water, that it does not separate from them when agitated, for several days, with a heat of eighty degrees of Fahrenheit’s thermometer. While, therefore, this water is in its natural state, and is not acted on by any other body, the aërial principle remains quiet ; and, with the other principles, seems equally dissolved in the watery element. It is not, therefore, then confined by any external force, like the air of beer, cyder, champaign, and other huffy liquors, which, while they are closed in bottles or other vessels, by their fermentatory motion, generate more air than they can imbibe and keep dissolved ; so that much of the air, so generated, is pent up in a confined state, and continually presses on every side, until a vent is given it, and then it rushes out with violence.

But, from the foregoing experiments, it appears, that this subtile elastic fluid, while it is associated with

the other principles of the Pouhon water, and is kept from contact of common air, and of such other bodies as are found to decompose this water, it remains in a quiet dissolved state, intimately mixed with the other principles of which this water is composed, and so closely joined to them, that it is not readily separated from them by a less heat than that of 100 degrees of Fahrenheit's thermometer; which heat it endures for several hours, before it is entirely detached from its union with them. It also appears, from the above experiment, that in proportion as this mineral air is separated by heat, in the same proportion the more gross earthy parts of the water seem also to separate from it; and that as the mineral air is thus entirely expelled, the water is then wholly decomposed, its metalline and earthy particles having subsided, its more volatile and elastic principles being exhaled, and nothing remaining in the water, save only the small portion of alkaline and neutral salt, which is found dissolved therein.

It may here be noted, that the numerous analyses of these waters, which have been attempted in retorts and receivers *, where the water was exposed with a large surface to the common air, the elastic substance seems to have been extracted from the water more readily, and with less heat than in the preceding experiment; and pellicles have sometimes been observed † on the water in the retort, as on the same water exposed to the open air; the causes of which phenomena will be explained hereafter.

* See De Presseux, Chrouet, Le Dran, Limbourg, Lucas, &c.

† See De Presseux.

EXPERIMENT III.

In order to ascertain the quantity of air contained in the Pouhon water, a Frontiniac vial was therewith filled at the fountain, on a clear morning, when the wind was easterly, and a strong swine's bladder, well freed from air, was immediately fitted thereto; all the air was then carefully expelled from this water by the heat of the bath, after the manner related in the foregoing experiment. The vial, with its contents, as soon as cold, was placed, in an inverted position, over a cistern of common water (as in Fig. 2.) so that the air, which had been expelled from the water, ascended to the upper part of the vial, while an equal bulk of the water contained in the vial descended into the bladder. When all the air had ascended into the vial, the height at which the water stood therein was marked with a diamond. The bladder being then removed, the vial was carefully closed with a cork, and then taken from the cistern; and the air which it contained was kept therein, until it was wanted for the use which will be mentioned hereafter.

As soon as the vial was emptied of the air and water which it contained, and had been exactly weighed, it was filled a second time with the Pouhon water, which was found to weigh twenty ounces, seven drachms, and fourteen grains, apothecaries weight. The vial was then emptied to the marks at which the water had stood therein, when in an inverted position; and the water remaining in the vial (which now filled the space that had before been occupied by the
air

air extracted in the above-mentioned process) was found to weigh eight ounces, two drachms, fifty grains. So that the bulk of the air extracted from the Pouhon water was to the bulk of the water from which it had been extracted, nearly as $8\frac{3}{8}$ to $20\frac{7}{8}$. Or, if we choose to reduce the above quantities into cubic inches, and allow a cubic inch of water to weigh 265 grains, we shall find, that in this process $15\frac{4}{5}\frac{0}{5}$ cubic inches of air were extracted from $37\frac{2}{5}\frac{9}{5}$ cubic inches of the Pouhon water.

From the above experiment it appears, that a very large quantity of air is contained in the Pouhon water: and a way is pointed out whereby the proportion of the bulk of air to that of a certain quantity of water, from which it had been extracted, may be exactly determined. Altho' this proportion must vary considerably in many waters, according to the weight and heat of the atmosphere, or the dryness or moisture of the season, at the time that they are taken from the fountain; and will also vary with the different degrees of expansion of the atmosphere, at the times that the different quantities of air are measured; I do not, therefore, give the above proportions for such as always hold; neither do I assert that they most commonly take place. I rather suspect the contrary; and, from other trials, am apt to believe, that a larger proportion of air is usually contained in the Pouhon water, than that which I obtained in the above experiment. For, when a boiling heat was used, the necks of the bladders were apt to shrivel, and became liable to crack on the least motion; so that it was difficult to confine the air in them. Had I had an opportunity at Spa of prosecuting this
experiment

experiment further, I should have attempted to have extracted all the air by a milder heat of about 110 degrees, in vials inverted in the water bath; so as that, while the air arose into the vials, an equal portion in bulk of the water might have been received into bladders fitted to them; or should have made use of other methods, which I shall have occasion hereafter to describe.

EXPERIMENT IV.

I took a glass receiver, of a cylindric form, near $5\frac{1}{2}$ inches high, and $3\frac{2}{3}$ inches in diameter, which contained 25 oz. 150 grains of water, Troy weight; or in measure $45\frac{2}{3}$ cubic inches, according to the above calculation of 265 grains of water to the cubic inch. This receiver being immersed in a cistern of water, was there turned, with its mouth downwards, and then raised, thro' a hole in a board fitted to the top of the cistern, as in Fig. 3. The receiver was there firmly secured with wedges, in such manner as to continue full of water, the lower part of it remaining immersed in the water of the cistern. I then took a Frontiniac vial, which contained nineteen ounces five drachms of water: this was filled with fresh pure air, by emptying it of the water in a cool open place, and then stopping it with a cork. The vial, thus filled with air, was placed, in an erect position, under the receiver; and the cork being taken out, the air ascended into the receiver, as it was forced out of the vial by the water rushing into it. Into this air a mouse was conveyed, by placing it on a round piece of cork, and plunging it quickly thro' the

the water into the receiver, in which it floated on the cork. In this air it lived for an hour in great ease, breathing with freedom, and diverting itself, while wet, with drying its face and head with its paws, like a cat. After having thus lived an hour in this close prison, it was taken out of it, thro' the water, by the same way that it had been conveyed in, and did not seem to have received any harm by this confinement, and by passing thro' the water; as after twenty-four hours, by the help of proper food, it was found as lively and active as it was before it had been thus treated.

§ 2. A small bird, viz. a green wagtail, being treated in the same manner, continued for an hour in the receiver in the same quantity of fresh air. It breathed three quarters of that time with great ease, but, towards the end of the hour, quicker, and with some struggle. Soon after it was taken out, it grew lively, and again breathed with the same freedom as before the experiment.

Our countryman Mayow asserts, that a fourteenth part of the air, in which these small animals are confined, is consumed by them before they expire. His experiments merit to be further verified. The experiments here related, which differ in several respects from those of Doctor Mayow, seemed necessary, in order to shew that these small animals can live commodiously, for a considerable time, closely confined in the above-mentioned quantity of pure air; and that they suffer no harm in passing into and out of the receiver.

By the way, I beg leave to remark, that by filling vials with dry sand, instead of water, here used, and emptying

emptying them in the Grotto di cani, or other deadly caverns, those mephitic exhalations (of which so many of the antients, as well as the moderns, have so much and so variously written) may be collected, and conveyed to a great distance ; and, when duly examined, will, doubtless, be found true, permanent, mineral air, of that kind known to our miners by the name of Choak-damp. Of which sort the air of the mineral water of Spa appears also to be, from the following experiment.

EXPERIMENT V.

I took the air which, two days before, I had extracted from the Pouhon water, as related in Experiment III. This air I emptied out of the vial into the receiver fixed in the cistern, in the manner described in the foregoing experiment. Into the same receiver I also emptied a bladder of air, extracted from the Pouhon water four days before. Which two parcels of mineral air filled as much of the receiver as had before been filled with common air, in the last-mentioned experiment. Into this mineral air, thus included in the receiver, the mouse was conveyed, which had been employed on the preceding day in the foregoing experiment. On passing into this air, it immediately held up its head very high, and turned it on every side ; and, in four or five seconds, without any difficulty of breathing, or other struggle, fell down on one side, and remained without motion. Half a minute after, it was taken out of the receiver, and placed on a table before a window in the open air, where it lay four hours with-

out shewing any sign of life, being quite stiff and dead.

Two other lively mice were successively treated in the same manner. The appearances in these were exactly the same as in the first. Both of them, after they had been in the mephitic air a few moments, fell down motionless, and were taken out dead. And tho' the last of the three was taken out of the receiver as soon as possible after it ceased to move, yet it never after shewed the least sign of life. The same experiment was, some days after, tried in air fresh extracted from the Pouhon water, on two of the small birds mentioned in the foregoing experiment; in which air they, in like manner, also soon expired.

By way of Scholia to the last experiments, I beg leave to refer to what I have written concerning the mineral elastic spirit of the acidulæ, in my fourth Essay on Damps, and other Mineral Exhalations, which is in the possession of the Royal Society.

I shall not now detain the Society any longer with more of my experiments; but, if these should be thought worthy of its notice, shall, hereafter, communicate other methods of extricating the air from the Pouhon water, as well by heat, as by other mediums; and, from proper observations and experiments, shall endeavour to explain the modus of the union of this subtil elastic fluid and the other principles with which it is combined in these waters, together with the relation that it bears to common air, and to several other bodies. Which observations and experiments may, perhaps, be thought worthy the attention of those who hereafter may make enquiries
concerning

concerning the nature and virtues of these, and several other mineral waters.

W. Brownrigg.

Whitehaven, 18 May, 1765.

Explanation of TAB. VII.

Fig. 1. A Frontiniac vial filled with Pouhon water, with a bladder and spiral wire fitted thereto, as described Exp. ii.

Fig. 2. Another of the same vials placed in a cistern, in an inverted position, as related Exp. iii.

Fig. 3. A glass receiver, of a cylindric form, fixed over the cistern (AA) in an inverted situation, so as to remain full of water, until air is transferred into it, from the vial (B), or from other vessels, for the uses mentioned in Exp. iv. and v.

Fig. 4. A board, of a semicircular form, fitted to the top of the cistern (AA), with circular holes, and niches, for the vials, and receivers used in the last-mentioned experiments.

Extract from an Essay, entituled, On the Uses of a Knowledge of Mineral Exhalations when applied to discover the Principles and Properties of Mineral Waters, the Nature of Burning Fountains, and of those poisonous Lakes, which the Ancients called Avernus; which was read before the Royal Society in April 1741, and to which the Author refers in the foregoing Experiments.

A More accurate History of subterranean Exhalations would also further contribute towards the improvement of the Medical art, by leading us to a more perfect knowledge of the genuine principles of several kinds of mineral waters; and by teaching us how to apply them rightly, and how to account, in a rational manner, for their operations and effects upon the human body.

For it hath long been observed (1), that the chief energy and virtue of several mineral waters doth not reside in the more gross, saline, earthy, or metalline particles, which they imbibe in their subterraneous passages, but in a far more subtle and volatile principle wherewith they long remain imbued when closed in bottles; but when they are exposed in open vessels, this volatile principle soon takes its flight, leaving the waters dead and inert, and deprived of their former salutary qualities.

This subtle and fugitive principle is, therefore, fitly called the Spirit of mineral fountains. To extract which spirit in the form of a liquid, many have

(1) Vide Becheri Physica Subterranea, sect. ii. cap. iv.

employed much time and study, and others have also endeavoured to separate it from the aërial element of mineral waters; but all these attempts have proved vain and fruitless, since it is plainly incoercible, and can scarce be condensed into a visible body.

We, therefore, readily submit to the opinion of Dr. Fred. Hoffman, who, by many solid arguments and judicious observations, hath shewn (2), that this spirituous principle of mineral waters is an exceeding rare and subtile body, endowed with an expansive quality, or a kind of elastic aërial fluid; and therefore cannot be rightly distinguished from the air of mineral waters, as if they were two different principles.

This most delicate and subtile aërial spirit of fountains, the same judicious author observes, is as it were the life of several minerals, preserving them from corruption, animating them with a lively sparkling and briskness, and inspiring them with wonderful and excellent virtues, which they exert in removing many obstinate disorders; and hath hitherto remained inimitable by art.

Neither is there any reason to doubt that bodies so extremely rare and subtile, as are the spirits of fountains, are capable of imparting such remarkable qualities to mineral waters. The great power and force of action, wherewith many kinds of mineral expirations are endowed, sufficiently appears from the observations (3) before related. And those who are unacquainted with the wonderful efficacy of exhalations,

(2) Fred. Hoffman, de aquis mineralib. indagandis, § 16. & Id. De Convenientia Elementor. & Virium, &c. § xix.

(3) Helmont, Complexionum atque Mistionum Elementalium figmentum, § 43.

tions, and their manner of operating upon the human body, may receive ample satisfaction from Boyle in his treatise of Effluvia. The sagacious Helmont, therefore, very judiciously recommends a more frequent use of those furious incoercible spirits, and volatile fumes, in the practice of physic; justly observing that no other medicines operate so suddenly and so powerfully upon the human body (4).

Neither ought we, because those spirits of fountains are flatulent and elastic, from thence to infer, that they agree with common air in every other respect, as many are apt to imagine. For corpuscles, which differ extremely in magnitude, density, and figure, may all be endowed with one common repulsive quality. And it is highly probable that the elastic particles, which are emitted from various kinds of dense bodies, do thus vary one from another; and that they oft-times compose elastic fluids, which differ as much from each other, as those bodies differ from which they are produced. Thus the air of pease, which is inflammable, seems to differ as much from the mephitical air of oak, which extinguishes flame, as those two vegetable substances differ between themselves. So that two elastic fluids, altho' they both possess a repulsive quality, may yet in their other qualities differ as much as inelastic fluids are found to differ; as water, for example, differs from oil of vitriol. The particles, therefore, of dense bodies, when they are separated from each other, and assume a repulsive quality, are not always reduced to common air, but to different kinds of elastic fluids,

(4) In the preceding Essays on the Fulminating-damp, and the Choak-damp.

which

which frequently retain the qualities of the dense bodies from which they were generated ; and which, by being reduced to an elastic state, become more active and penetrating, and operate much more suddenly and violently upon the human body ; as the fumes of quicksilver, and the vapour of water, by their effects, do sufficiently prove.

Now, as these subtile and elastic spirits do frequently exert very sudden and violent effects upon the human body ; and entering the composition of mineral waters, often endow them with excellent virtues ; it may, therefore, be useful to examine the origin of those spirits which are found in fountains, and to consider in what manner water becomes impregnated with them as it passes through the bowels of the earth. To determine which questions, those observations will greatly contribute, which we have already given concerning the generation of the fire-damp, and its lodgment in the cavities of earth. For as the fire-damp is generated from sulphureous and ferruginous substances, and is often closely pent up with water, and intimately (5) blended therewith in the subterraneous cavities ; its particles, therefore, being impelled by their own elastic pressure into the pores of the water, will be dissolved therein, after the same manner as I have before shewn they may be dissolved therein by art. And in like manner, water will become impregnated with those other kinds of air and mineral exhalations, which are lodged in the subterraneous cavities thro' which it passes. The subterranean damps and mineral spirit of fountains seem,

(5) See Essay on the Fulminating-damp.

therefore,

therefore, exactly to resemble each other both in their nature and origin. And of this opinion is the above-cited Fred. Hoffman, who seems in every respect qualified to have advanced the knowledge of mineral waters to its highest perfection, had he been furnished with a more accurate history of mineral exhalations. By means of such an history, he would probably have been enabled to distinguish the spirits of mineral fountains into their different kinds, which he now seems to confound together, as if they were alike in every respect. Altho' 'tis not improbable, that as there is a great variety of subterranean exhalations, so also there may be various kinds of mineral spirits; and that water may be capable of imbibing several kinds of those exhalations which it meets with in the bowels of the earth. The Rev. Doctor Hales, in his Statical Essays, and Doctor Shaw, in his Inquiries into the Nature of the Scarborough Waters, have shewn various ways whereby these aerial spirits may be extracted. If, therefore, the spirits extracted from different mineral waters, by the ways which they direct, were carefully examined, and were compared with each other, and with the different sorts of mineral exhalations which are found in the earth, we might, perhaps, more easily distinguish their several kinds, and more exactly discover their resemblance to the several sorts of mineral exhalations, than by any other method which could be put in practice.

But, without having recourse to experiments of this kind, we may from other observations conclude, that the spirit of those waters which are called Acidulæ is nearly related to the choak-damp, or stith,
found

found in the coal-mines, and in various other parts of the earth.

For, subtile mephitic spirits have frequently been observed to expire from the earth in parts adjacent to many of the acidulæ, and to produce the same effects upon animals and other bodies as the stith or choak-damps, or as the spirits of the *Grotto di Cani* in Italy, of which, and others of the like nature, Leonardo di Capoa hath largely treated. Thus the learned Dr. John Philip Siep hath communicated to the Royal Society (6) a very accurate account of a grotto of this kind, which he discovered near the fountains of Pyrmont. Another grotto of the same sort Pechlinus takes notice of, nigh the acidulæ at Swalb in Germany (7). And the learned Hoffman was informed by a person of credit, that a fountain in the Black Forest, in the dutchy of Wurtemburgh, which had flowed a long time, was suddenly deprived of all its taste and virtue, by reason that in the neighbouring parts a mineral and sulphureous vapour impetuously burst out of a chasm which was made in the rock; but this chasm being closely stopt up, the fountain again obtained its former virtues (8).

And that the acidulæ are really impregnated with a mephitic exhalation resembling the choak-damp, some of these springs (as those at Pyrmont) do plainly discover by their deadly effects upon ducks swimming upon their surface (9).

(6) Philosoph. Transactions, N^o 448. pag. 266.

(7) Pechlinus, lib. iii. Obs. 44.

(8) Hoffman, De Principiis & Virtutib. præcipuor. Germaniæ Medicator. Fontium, § xxxv.

(9) Dr. Philippus Siep. Ibid.

To the same spirits may also be attributed the power which the acidulæ possess, of causing a giddiness of the head, heaviness, and drowsiness, as from intoxicating liquors.

The brisk and pungent taste of the acidulæ is also a further evidence that the mineral air which they contain is nearly related to the choak-damp. For from this brisk pungency of taste, these spirits appear to resemble the air which is generated from beer and other liquors by fermentation. But the air of fermenting liquors is by numerous experiments discovered to be a deadly poison when applied to the lungs, and the external parts of the body, acting chiefly upon the nervous system, and instantly killing those animals which breathe it, exactly in the manner of the choak-damp. Yet nevertheless this air, when taken inwardly in a convenient quantity of a liquid vehicle, is found to have wonderfully exciting and reviving qualities, of which the case of Cornaro affords us a remarkable instance (10).

In like manner, the elastic spirit of the acidulæ seems to have a great share in the admirable effects which those waters exert upon the human body. For being exceedingly subtile, penetrating, and active, it seems fitted to pervade the whole body, and to force a passage through the minutest vessels; by its mild and gentle stimulus, to corrugate the fibres, increase their elasticity, and excite them to motion; by its expansive quality, to rarify and as it were spiritualize the blood, and dilate the vessels. By these several

(10) See Discorso terzo della Vita sobria di Sig. Luigi Cornaro, pag. 87.

ways, therefore, it may greatly contribute to strengthen the solids, to accelerate the motion and circulation of the fluids, and to warm and invigorate the whole animal frame. So that to these spirits seem in a great measure owing the virtues which the acidulæ possess, of attenuating the humours, breaking their unnatural concretions, and powerfully opening obstructions ; of provoking the appetite, assisting the digestion and concoction of the aliment, and facilitating all the natural secretions and excretions of the body.